KOREA ATOMIC ENERGY RESEARCH INSTITUTE

Korea's 2050 Power System Scenarios: Generation Mix, System Cost and Implications

2050년 한국 전력시스템 시나리오 분석: 전원구성, 시스템비용 및 시사점

Korean Nuclear Society Autumn Meeting 2026, Workshop | 28 Oct 2026 | Jay Cho (KAERI)

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

Study design

2050 snapshot: 4 study scenarios, 4 sensitivity families

Study scenarios: 2 demand levels × 2 large-nuclear caps

	Pull: large PWR cap 80.2 GW (assumes 2 new units/yr)	Push: large PWR cap 42.2 GW (low demand 35.1 GW)
Low demand 708.6 TWh SMR 14.3 GW	Low Pull	Low Push
High demand 1,001.9 TWh SMR 21.1 GW	High Pull	High Push

Reference baseline (not a study scenario): one long-term operation (LTO) round, no added build (large PWR 23.0 GW, SMR 0.7 GW), low demand

Sensitivity and diagnostic cases

VRE investment cost
Solar and wind investment cost 0.3×~2.0× (large nuclear 2,487 · 4,500 $/kW)

No HVDC
Run without the 8 GW Gangwon–Capital line

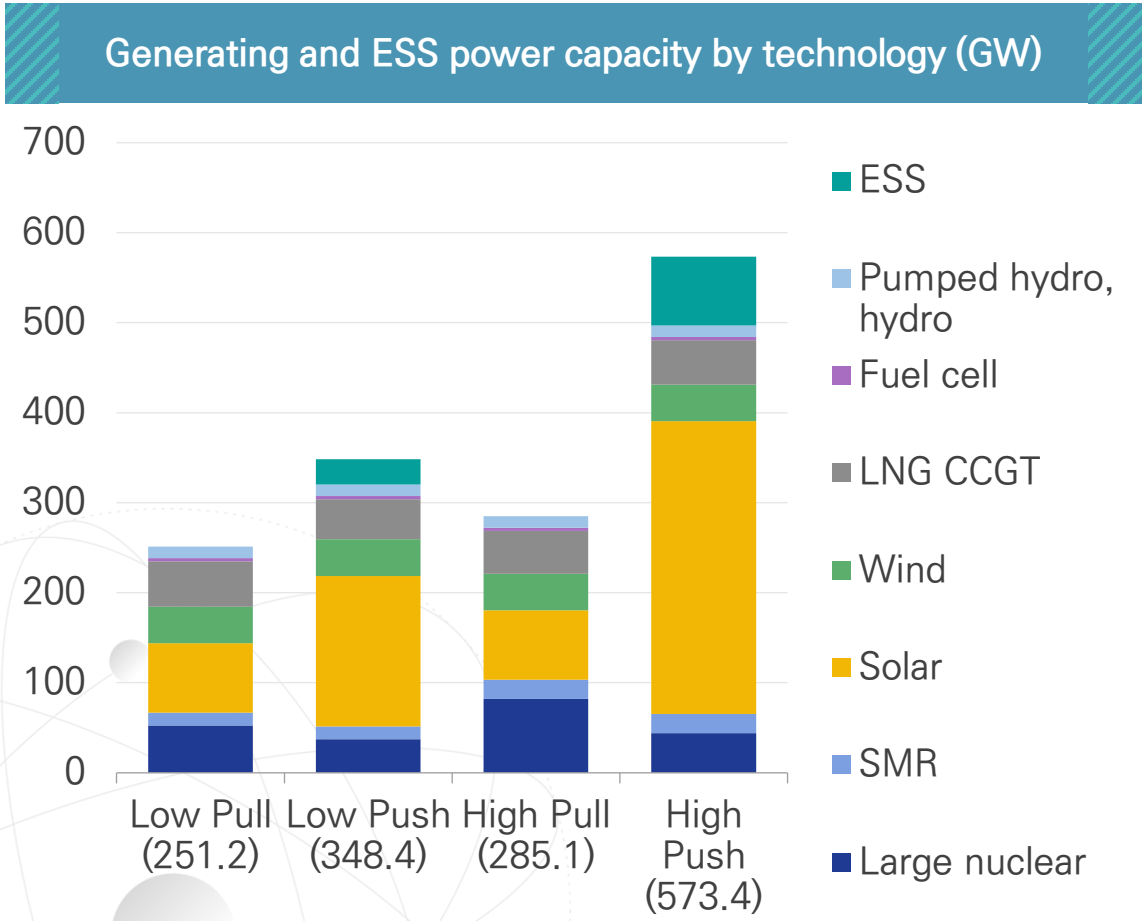
SMR siting
SMRs also allowed in Capital, Incheon and Jeju

CO_2 constraint
Cap 0~100 Mt, with and without CCS

Separate: fully endogenous (bounds released)
Capacity caps and floors released (large nuclear 2,487 · 4,500 $/kW)

Common assumptions: CO_2 cap 20.7 Mt, final consumption (excl. losses), SMR capacity fixed, 2023 weather, 2038 grid, 2024 USD

Same demand: Push builds more solar and ESS than Pull



Solar at its regional potential

High Push: 8 of 11 regions (highest build in any bounded run; 369 GW nationwide)

Push vs Pull, same demand

Solar 77.2 → 167.3 (low) · 77.2 → 325.4 GW (high); ESS 0.0 → 28.1 · 0.0 → 76.4; large nuclear 52.4 → 37.1 · 82.1 → 44.1 GW

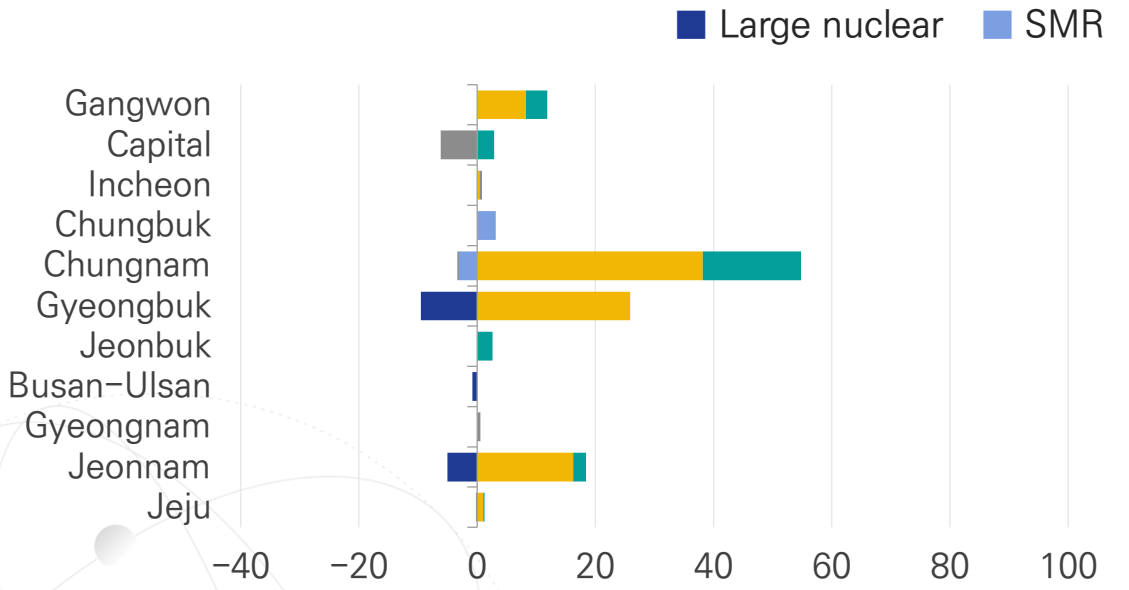
Same in Pull and Push

SMR, wind, pumped hydro and hydro, fuel cell: fixed or equal within each demand level

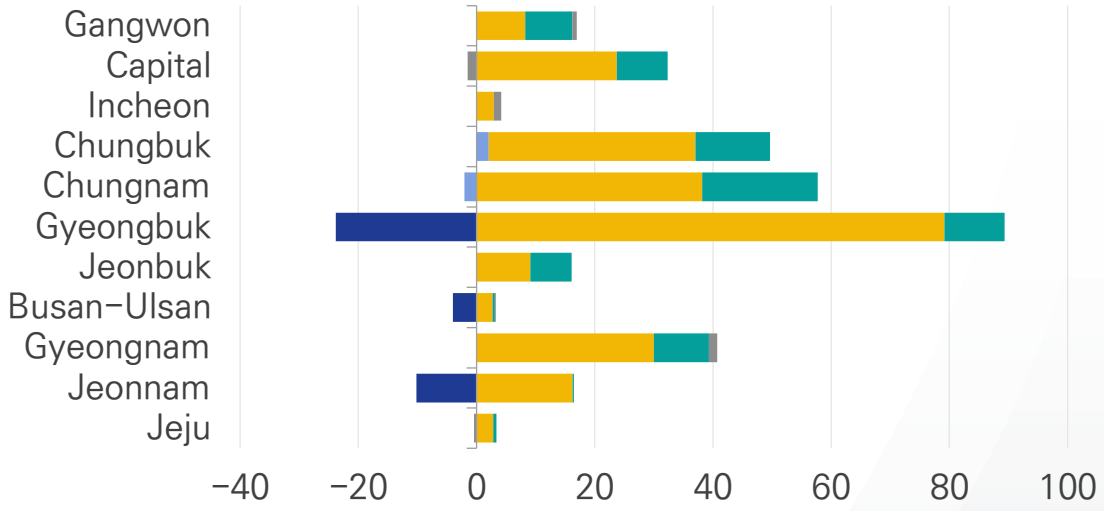
Column totals labelled (GW). Electrolysers are excluded from the totals. Reference baseline (not shown): 587.8 GW, solar 355.3 GW, ESS 94.2 GW

Push trades coastal nuclear for solar and ESS across regions

Low demand: capacity change, Push − Pull (GW)



High demand: capacity change, Push − Pull (GW)



What is built where

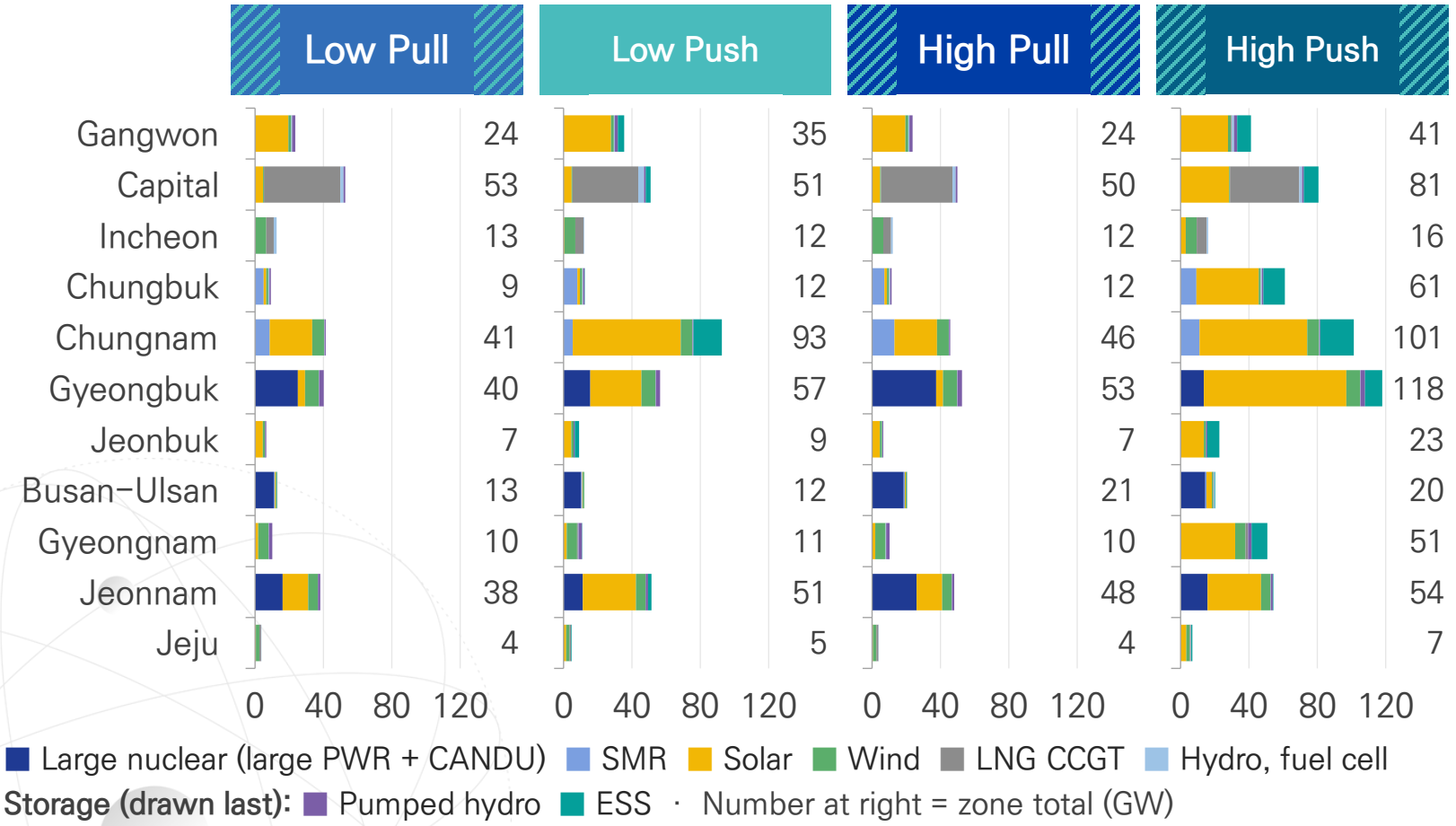
Large nuclear only on the coast (Gyeongbuk, Jeonnam, Busan–Ulsan; siting assumption): Push builds 15.3 / 38.0 GW less (low / high demand)

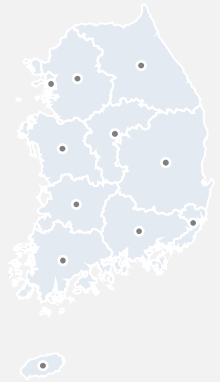
Solar and ESS

In Push, solar reaches its regional potential in 3 (low) and 8 (high) of 11 regions (Pull: 0 · 0), mostly with ESS beside it

Zones ordered north (top) to south; both panels on the same axis. Regional solar potential = the most solar any bounded run builds in that region (369 GW nationwide). Wind is unchanged by region. SMR total is fixed; only its location is optimised

Push adds the most net capacity in Chungnam, Gyeongbuk





The 11 zones

Bars list them north (top) to south, the same in every panel

Push − Pull, same demand

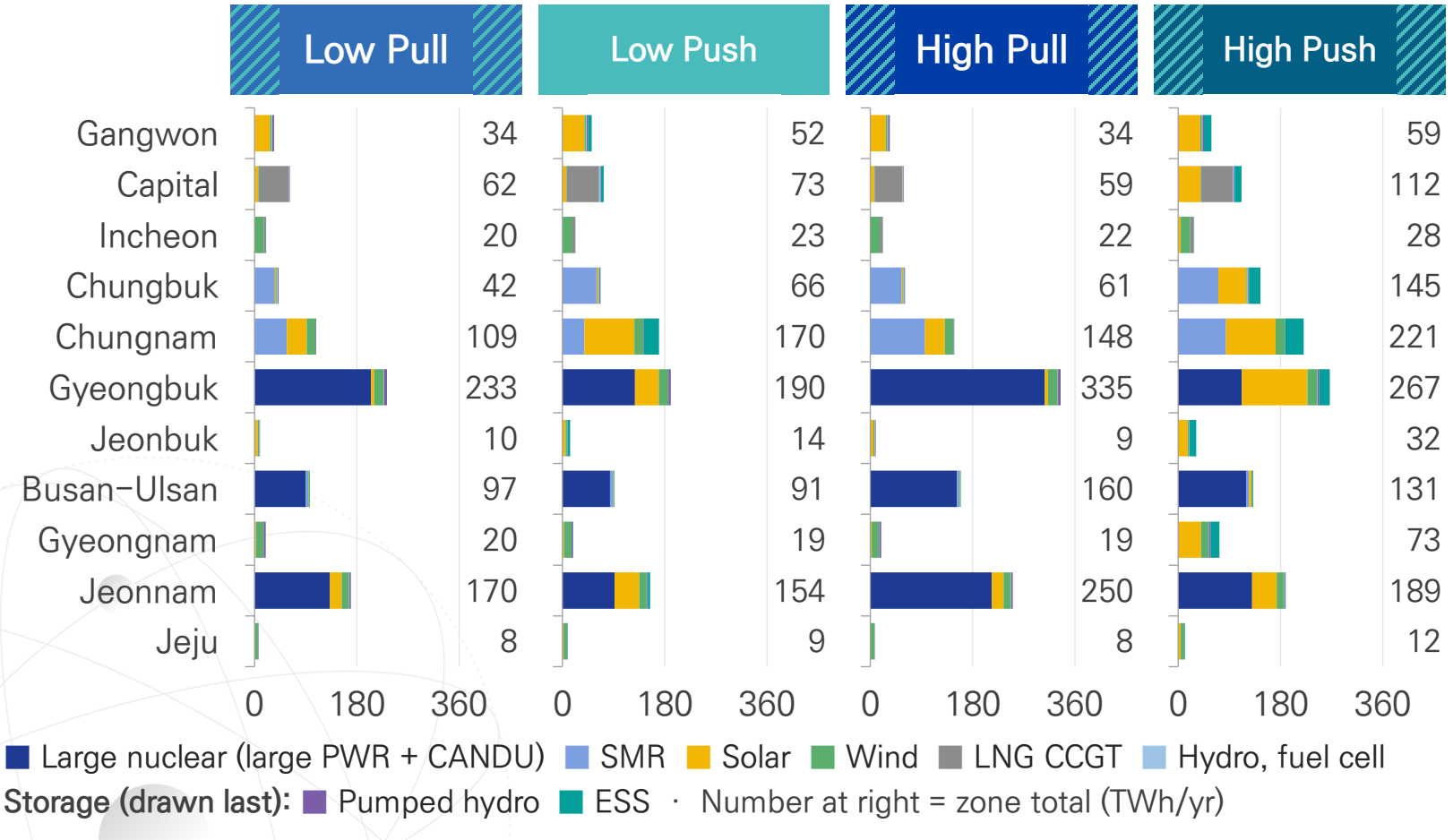
Low: Chungnam +51.3, Gyeongbuk +16.4 GW. High: Gyeongbuk +65.4, Chungnam +55.6 GW. Mostly solar, plus ESS (none in low-demand Gyeongbuk); Gyeongbuk is net of 9.5 / 23.8 GW less large nuclear

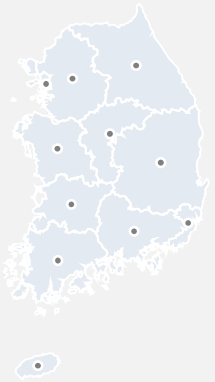
Largest zone

Low Pull Capital 52.8; Low Push Chungnam 92.7; High Pull Gyeongbuk 52.6; High Push Gyeongbuk 118.1 GW

Zones north (top) to south; one axis for all panels. Large nuclear = large PWR + 1.95 GW CANDU (Gyeongbuk). Hydro, fuel cell = conventional hydro + fuel cell. Pumped hydro ≤ 2.6 GW per zone: plotted, thin at this scale. Map: provinces aggregated to the 11 zones; dots = representative zone locations, not substations

Push moves output out of the three large-nuclear zones





The 11 zones

Bars list them north (top) to south, the same in every panel

Push − Pull, excl. storage discharge

Gyeongbuk, Jeonnam, Busan-Ulsan −64.9 / −175.0; Chungnam, Chungbuk +59.1 / +104.3 TWh (low / high). High also: Capital +40.1, Gyeongnam +38.3

Largest producer

Gyeongbuk in all four: 29 / 23 / 30 / 22% of generation excl. storage

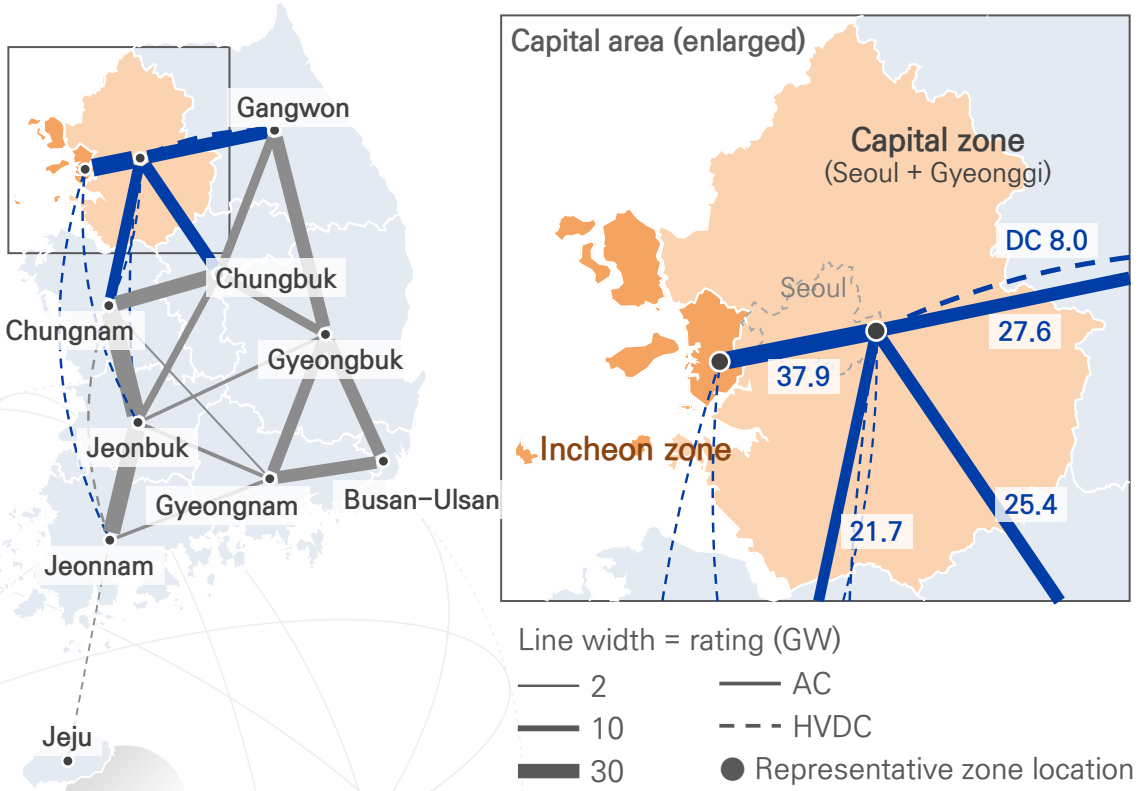
Storage discharge

19.4 / 60.9 / 17.3 / 140.1 TWh; not in shares

Bar = production incl. storage discharge (pumped hydro, ESS; drawn last). Shares exclude storage discharge. Pumped hydro ≤ 5.4 TWh/yr per zone: plotted, thin.
Map: provinces aggregated to the 11 zones; dots = representative zone locations, not substations

The Capital area depends on transfers over a fixed 2038 grid

Model zones and 2038 links (transfer capability, GW)

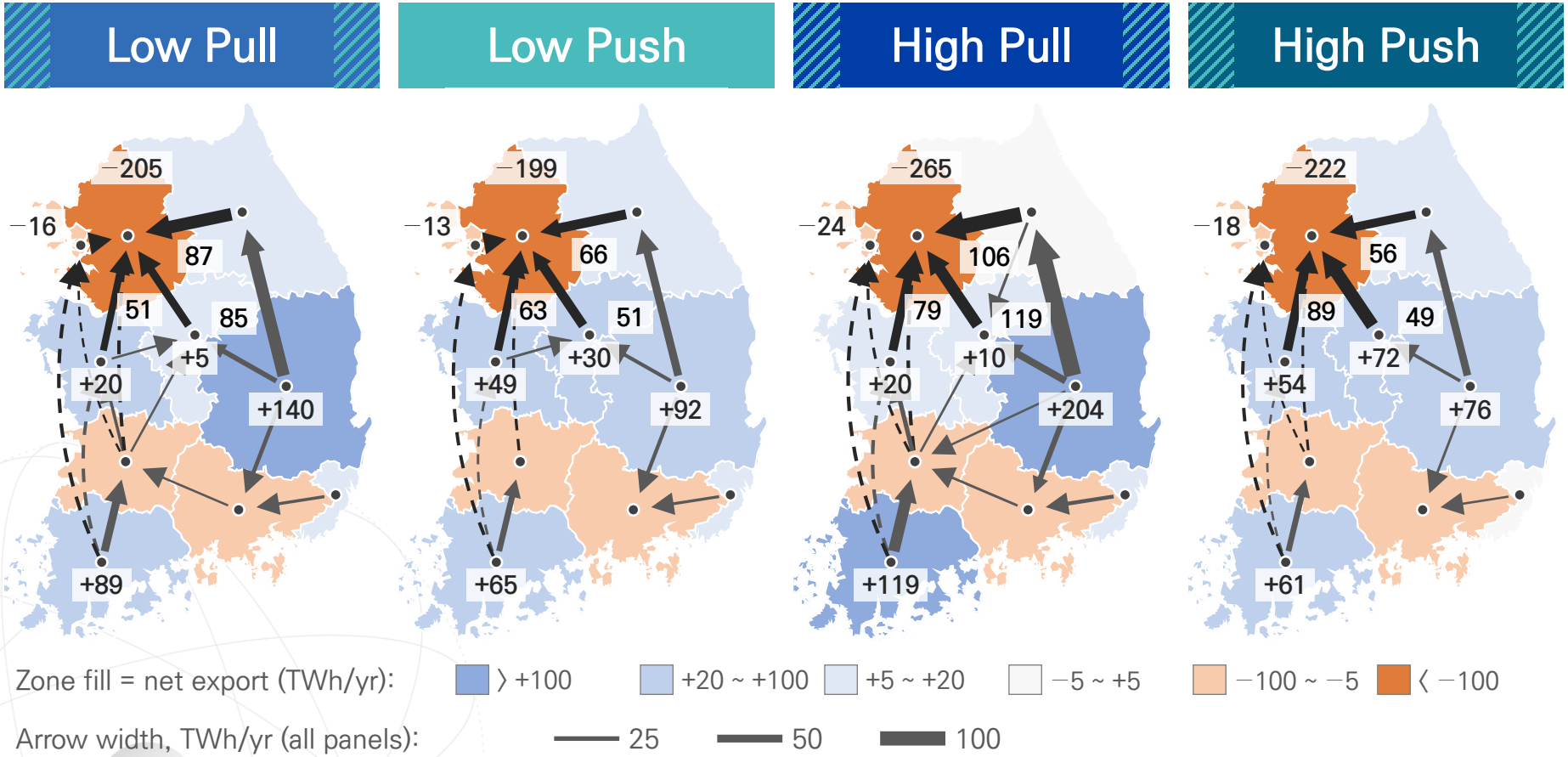


Fixed 2038 grid

Transmission is a key issue for the Korean system. Here the 2038 grid is fixed and expansion is not optimised

GW = transfer capability (link rating); TWh = annual energy. Map: provinces aggregated to the 11 zones (Daejeon, Sejong → Chungnam; Daegu → Gyeongbuk; Gwangju → Jeonnam). Dots = representative zone locations, not substations; lines = schematic zone–to–zone links, not routes. Ulleungdo, Dokdo and the far western islands not shown

Push shifts Capital supply from Gangwon toward Chungbuk



High Pull loads one route

Gyeongbuk large nuclear 37.5 GW (High Push 13.7): Gyeongbuk → Gangwon 119.3, Gangwon → Capital 105.8 TWh/yr (High Push 48.6 / 55.7)

High Push

Chungbuk sends 89.3 TWh, now the largest source; Gangwon 55.7

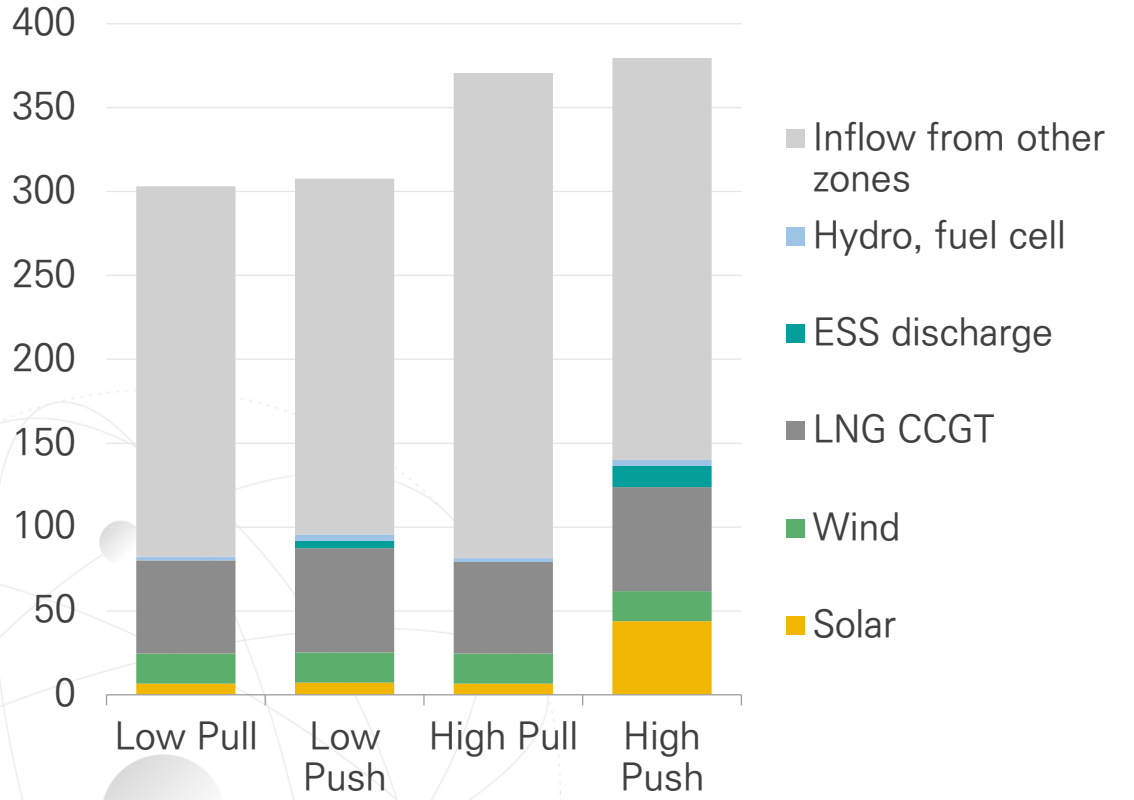
Net export, high demand

Pull → Push: Gyeongbuk 204.4 → 75.7, Jeonnam 119.0 → 61.0; Chungbuk 10.4 → 71.6, Chungnam 20.0 → 54.3

Arrows: net annual transfer per zone pair (gross A→B minus B→A), TWh/yr, AC and HVDC combined; dark = into the Capital area; ≥ 5 TWh/yr drawn. Values at dots = zone net export. Relaying is read from annual flows, not traced hour by hour. Jeju not shown (net import 1.8 TWh/yr or less). Dots = representative zone locations, lines = schematic links (not substations or routes)

Capital area: inflow from other zones = 70~84% of its use

Capital area: local generation and inflow (TWh/yr)



Consumption

280.3 / 343.2 TWh/yr (low / high demand); Capital zone (Seoul + Gyeonggi) 246.8 / 300.0, Incheon 33.5 / 43.2

Local generation incl. storage discharge

81.4~139.9 TWh/yr; LNG the largest source (54.7~62.2); Incheon wind 16.7 in every scenario; High Push solar 43.9

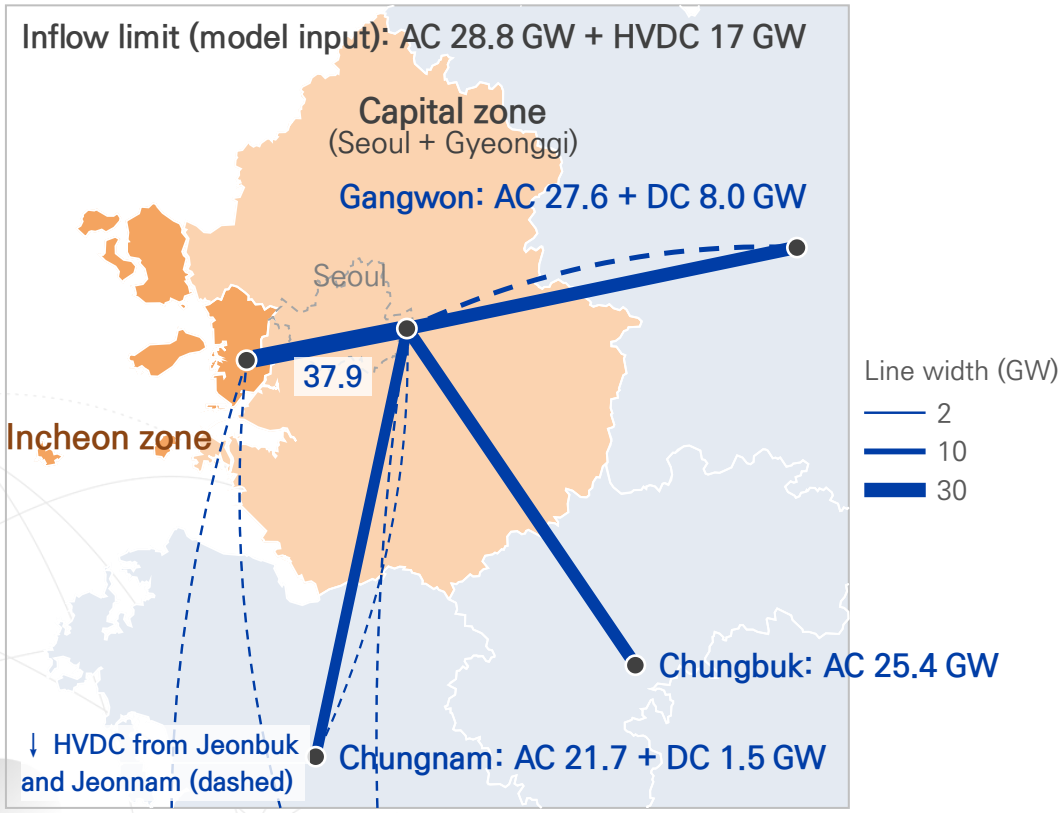
Inflow from other zones

212.3~289.3 TWh/yr = 70~84% of use

Bars = annual energy supplied to the Capital area (local generation in both zones + inflow from other zones); it also covers charging, losses and exports. Transfers between Capital and Incheon are internal and not shown

Capital–area inflow saturates at its limit in all four scenarios

Links into the Capital area: rating (GW) and HVDC use



Hourly peak (model output)

44.7 GW in all four scenarios ≈ 28.8 GW AC limit + 15.5 GW HVDC. Inflow is near the limit (within 0.5%) for 42~909 h/yr

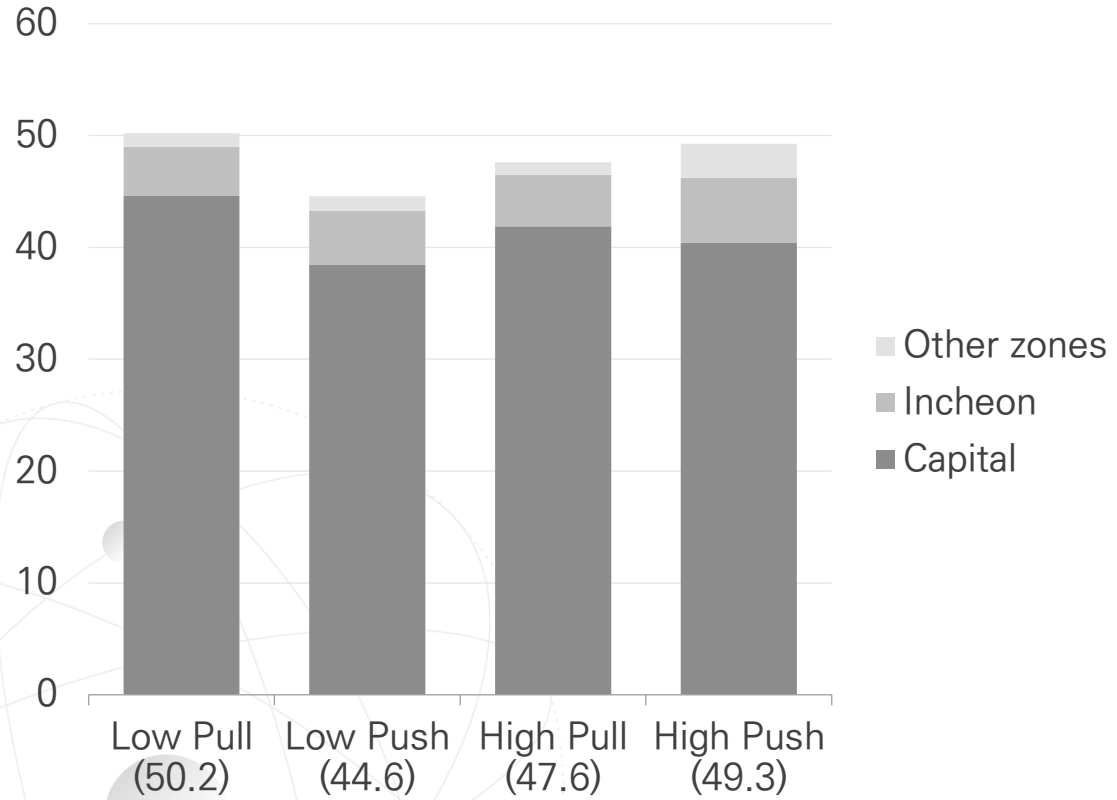
Southern HVDC (DC 2.0 GW each): saturated h/yr

of 8,760 h · Low Pull · Low Push · High Pull · High Push
Jeonbuk→Capital: 7,815 · 5,010 · 8,622 · 4,217
Jeonbuk→Incheon: 1,359 · 1,116 · 4,331 · 1,893
Jeonnam→Incheon: 8,461 · 6,939 · 8,723 · 7,223

Hourly flows combine AC and HVDC per zone pair, so hours at the AC limit cannot be counted exactly. Line width = rating (GW). Dots = representative zone locations, lines = schematic links (not substations or routes)

Most LNG capacity (94~98%) sits in the Capital area

LNG CCGT capacity by zone (GW)



Share in the Capital area

Low Pull 97.6% · Push 97.1%
High Pull 97.7% · Push 93.9%

Capacity factor (national)

Low Pull 12.8% · Push 16.1%
High Pull 13.4% · Push 14.5%

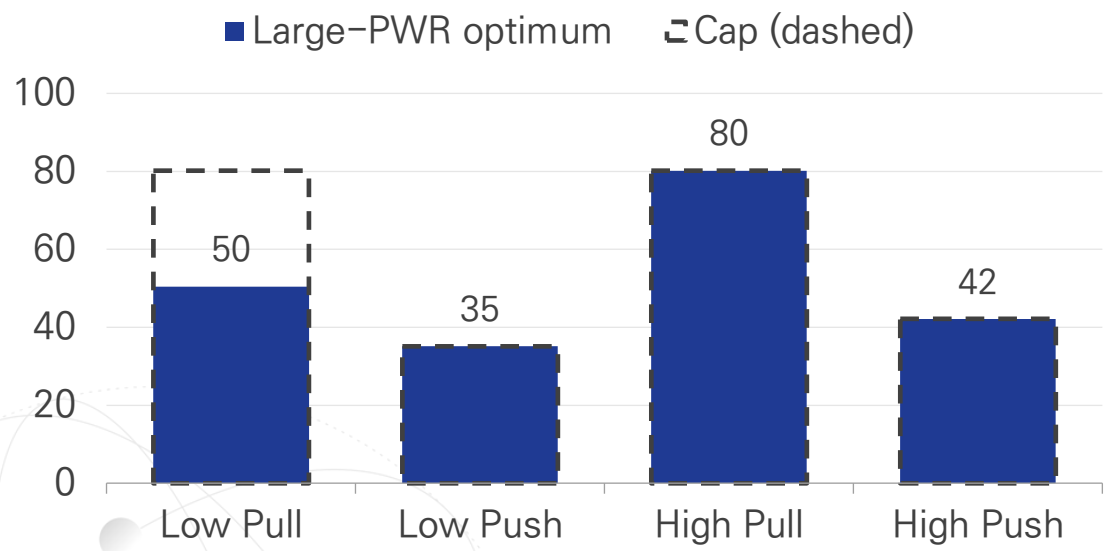
Seasonal use (model output)

77~80% of LNG output falls in months 1–2 and 7–9 (winter, summer); spring and autumn 10~16%

Generation: Push 62.8 TWh/yr (LNG emits the full 20.7 Mt of CO_2), Pull 56.2 · 55.7. CCS and hydrogen CCGT are not in the four scenarios

Large PWR hits its cap in all Pull/Push cases except Low Pull

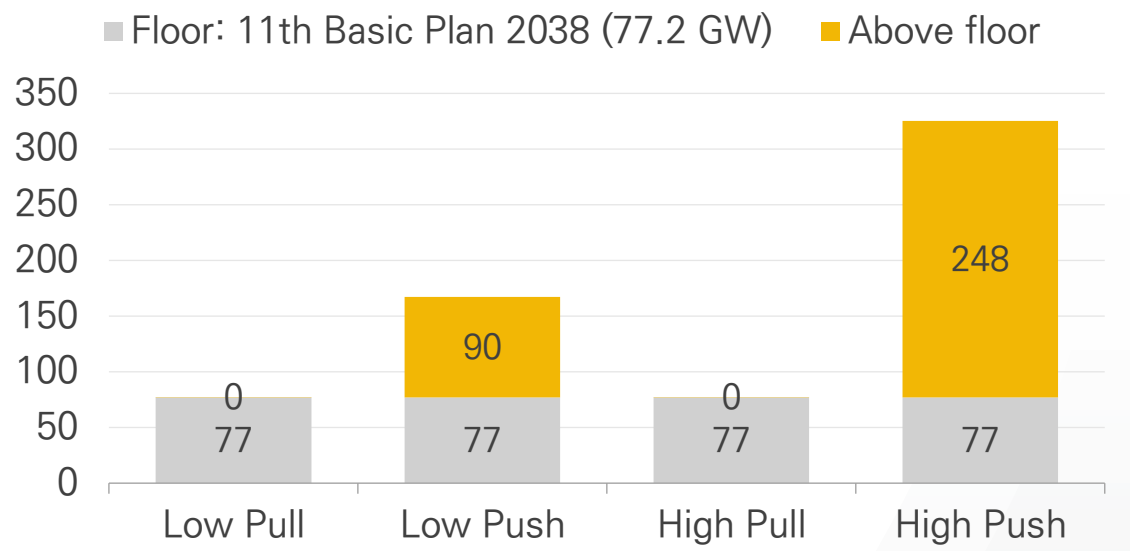
Nuclear: optimum and cap (GW)



Is the large-PWR cap binding?

Push: 35.1 / 42.2 GW at the cap (binding) in every sensitivity. Pull: low demand 50.4 GW (below cap), high demand 80.2 GW (at cap)

Solar: floor and build above floor (GW)



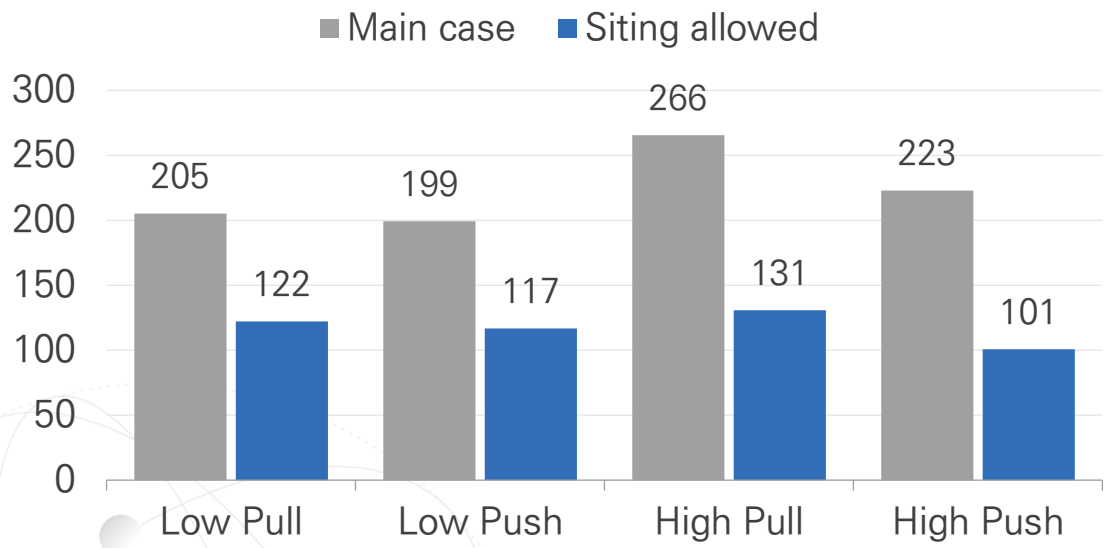
Wind stays at its floor

Onshore wind 24.4 GW: floor equals regional cap, so not set by optimisation. Offshore wind stays at its floor in all four scenarios (above it only in the Reference baseline, 20.3 GW)

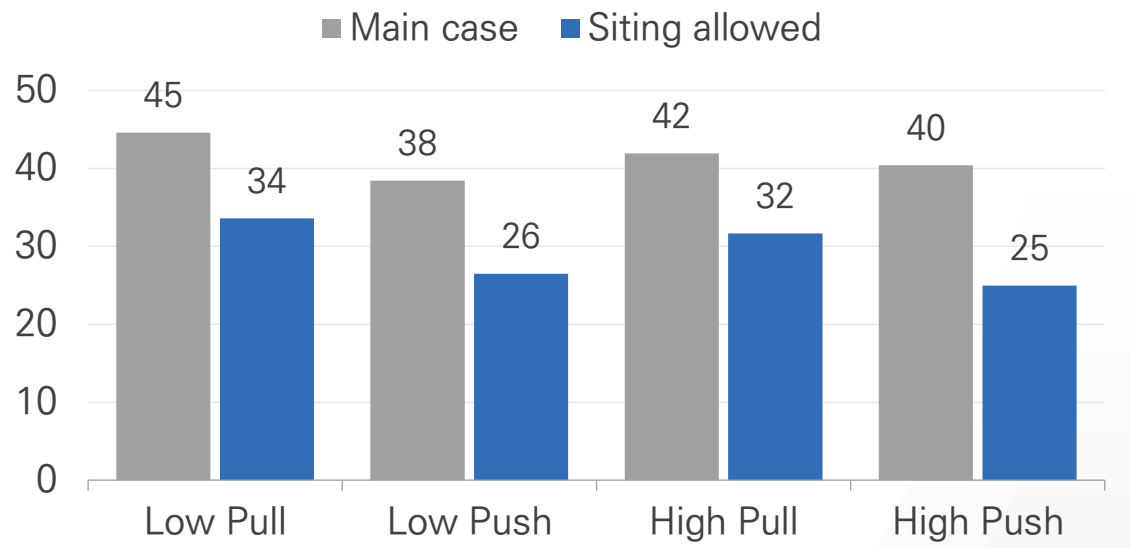
Floor = minimum capacity required in every case: the 11th Basic Plan (전기본) 2038 solar 77.2 GW and wind 40.7 GW; the model may build more, not less. Large-PWR cap = LTO fleet 23.9 GW + 4 units under construction + new 2032~2049 (Low Push 4, High Push 9, Pull 36 units); 1 unit ≈ 1.41 GW

SMRs allowed in the Capital zone cut its imports 40~55%

Capital-zone imports (TWh/yr)



Capital-zone LNG capacity (GW)



Where the SMRs go

SMR total per demand level unchanged; 13.6~20.4 GW moves into the Capital zone. Flows from Chungbuk and Chungnam fall most (High Pull 78.7 → 19.9 TWh from Chungbuk)

Local LNG and national cost

Capital LNG falls 10.2~15.4 GW. System cost falls 0.23~0.91 B$/yr (under 1%); losses fall 1.1~1.6 TWh/yr

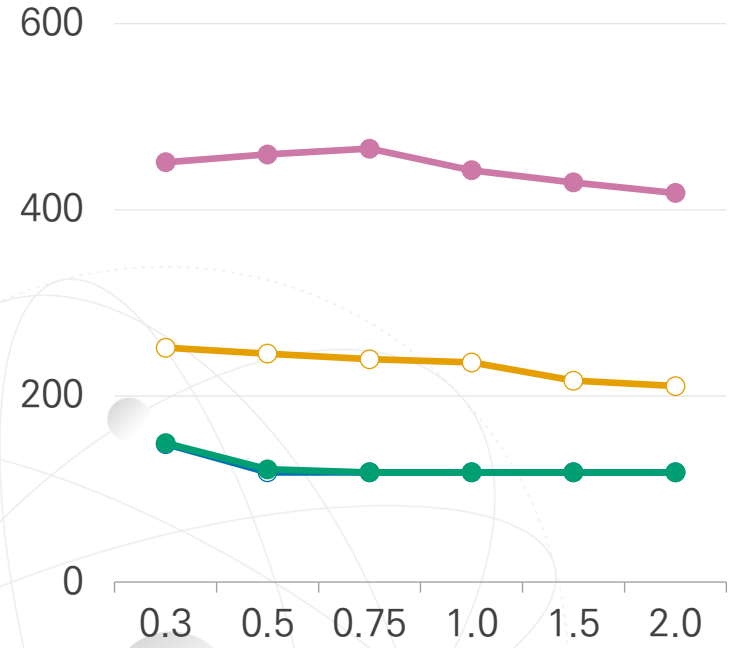
Public acceptance, safety regulation, cooling water and sites are not modelled. This result does not imply that Capital-zone SMRs are feasible

VRE cost reshapes the Push mix; Pull stays near its floors

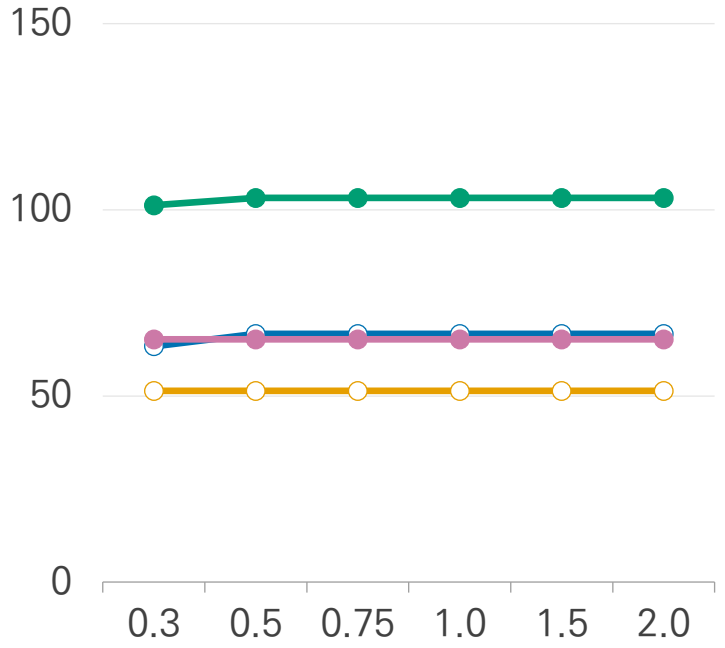
Capacity by VRE investment-cost multiplier (×)

Low Pull Low Push High Pull High Push (low demand: open markers)

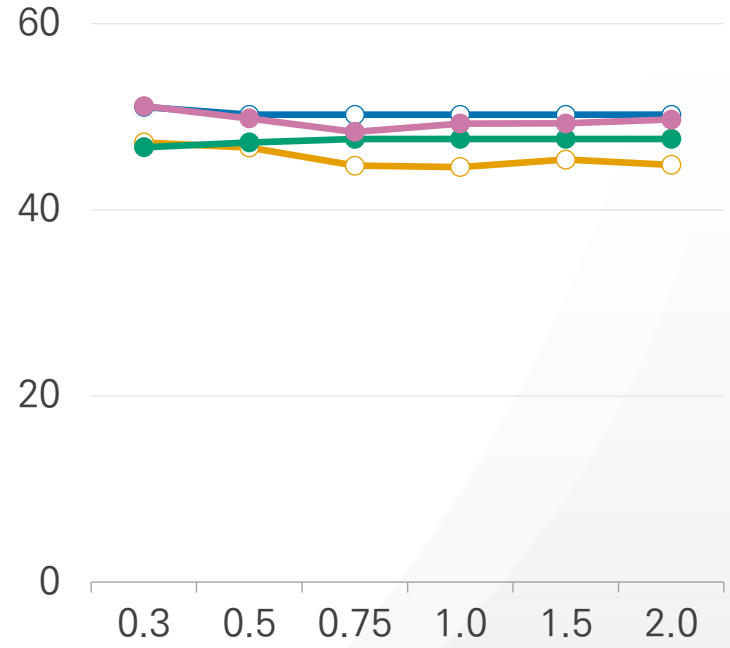
Solar + wind + ESS (GW)



Nuclear (GW)



LNG CCGT (GW)



Multiplier applies to solar and wind investment cost; ESS investment cost fixed; 1.0× = main case. Each panel has its own axis from zero. Nuclear = large PWR + CANDU + SMR (SMR fixed by scenario)

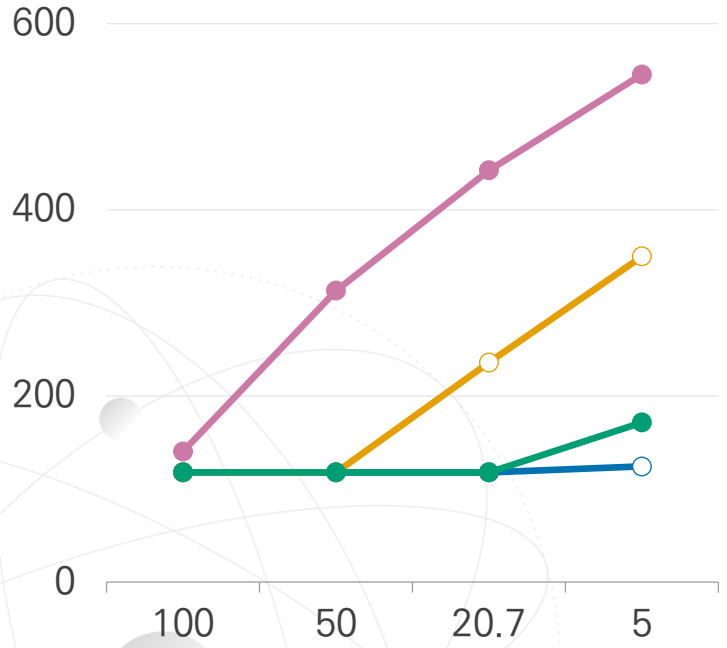
Sensitivity | CO_2 constraint

In Push, tighter CO_2 caps swap LNG for solar, wind and ESS

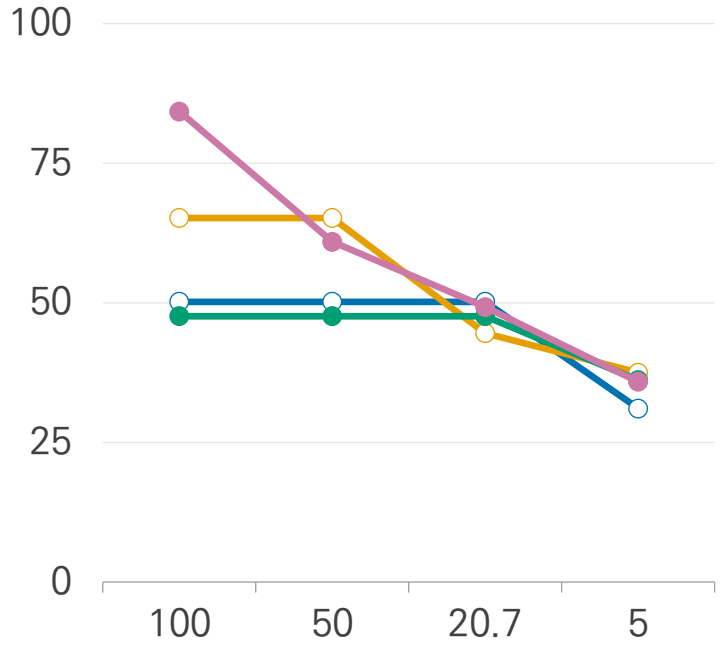
Capacity by CO_2 cap (Mt, no CCS)

Low Pull Low Push High Pull High Push (low demand: open markers)

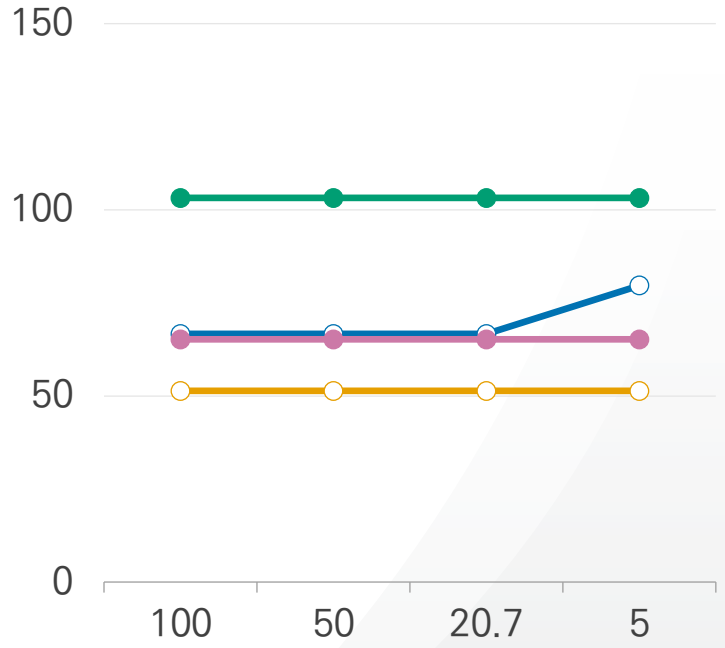
Solar + wind + ESS (GW)



LNG CCGT (GW)



Nuclear (GW)



No CCS; 20.7 Mt = main case. Each panel has its own axis from zero. Nuclear = large PWR + CANDU + SMR.

Three points to take home

1 All four scenarios are feasible; tighter constraints bring more challenges

Higher demand and a tighter large-nuclear cap mean more installed capacity in 2050 (251.2 GW in Low Pull to 573.4 GW in High Push). More nuclear (Pull) is the cheapest (Push +8.8% / +25.7% under the 20.7 Mt CO_2 cap) but not necessarily the easiest to build; plants and grid must be ready in time (presenter's judgement)

2 Nuclear policy changes where power is made

Push moves output out of the three large-nuclear zones (−64.9 / −175.0 TWh/yr, low / high demand) and builds mostly solar, plus ESS

3 The Capital area runs on transfers, up to its limit

Inflow from other zones equals 70~84% of its consumption in all four scenarios; inflow saturates at 44.7 GW ≈ the 28.8 GW AC limit + 15.5 GW HVDC

Single-year 2050 optimum on 2023 weather, the fixed 2038 grid and fixed SMR capacity; feasible = the model finds a solution, not a build plan

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Thank you

Jay Cho | KAERI | jcho@kaeri.re.kr

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